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Blended Hydrogen: The UK Public's Perspective

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About This Report

"There is a huge amount of enthusiasm for hydrogen heating, but there is a question about public perception and how much you can blend…"

Claire Perry MP, Former Minister of State for Energy and Clean Growth[1]

Hydrogen is increasingly being positioned as an important component of the UK's Net Zero ambitions and commitments. In particular, hydrogen could be an appropriate way to decarbonise the heat produced for domestic and industrial buildings. It is possible that hydrogen could replace natural gas in the UK gas network, achieving key carbon emissions reduction targets while enabling homes to be heated to a similar level and standard as they currently are.

In the interim, small amounts of hydrogen will soon be blended into current natural gas supplies. The premise of this idea is to blend hydrogen into the existing gas network in small enough quantities to not require any adjustments to domestic cookers, boilers, and other gas-fired appliances, but in large enough quantities to generate significant, immediate reductions in carbon emissions. Three trials will take place between 2019 and 2022 as part of the HyDeploy project, with the aim of demonstrating that hydrogen blending can occur at scale with no safety implications and no disruption to users.[2]

Public perceptions and acceptance of hydrogen will be pivotal in this scenario. At present, there is very little indication of how acceptable hydrogen will be for heating homes, and questions around safety, cost, and performance are only beginning to be understood and addressed.

This report investigates public perceptions of blended hydrogen as a fuel for UK homes. In March 2019 we administered a survey to a sample (n=742) representative of the UK adult population in terms of age, sex, ethnicity, and personal income. Our survey covered initial perceptions, values, and knowledge of hydrogen; the possibilities and pitfalls of hydrogen blending; public trust; and participants' overall support for hydrogen. **Key Findings and Conclusions** and **Recommendations for Policy and Practice** follow immediately, with the full report beginning on p.6.

Key Findings and Conclusions

1. Public knowledge and understanding of hydrogen and hydrogen blending is low

Our findings show that there is limited awareness and knowledge of hydrogen as a possible fuel for UK homes among the public. 64.4% of our respondents answered only one or none of our knowledge questions on hydrogen correctly, and the findings suggest a majority of our respondents felt that they did not know enough about hydrogen to give an opinion on whether or not it should be accepted as a fuel for UK homes.

2. Most people perceive hydrogen neutrally, and there is no sense of acceptance or rejection of it as a fuel for UK homes

Few of our respondents strongly accepted or rejected hydrogen outright. On a scale of -1 to 1, with -1 designating complete rejection and 1 designating complete acceptance, the average response of participants to our questions on hydrogen acceptance was 0.08. Hydrogen, then, may be considered a blank slate for much of the UK – there is little evidence that strong opposition or support for hydrogen currently exists among the public.

3. Once informed, support for and willingness to use blended hydrogen becomes moderately high

After being informed that UK appliances have been tested to run on 20% vol blended hydrogen, and that hydrogen-rich town gas was previously used in the UK, our respondents' willingness to use hydrogen increased. In addition, respondents rated their overall support for hydrogen as 7/10 and were not unsupportive of a blended hydrogen trial taking place in their local area.

4. Benefits for the environment are recognised, and the impacts on home use are perceived as minimal

Once informed, 70.6% of participants believed that using blended hydrogen would result in positive environmental impacts, while 61.7% of our respondents believed there would be no overall impact on their home appliance use. Taken together, this demonstrates that respondents envisaged a sustained, positive environmental impact without the necessity of changing their home appliances or the ways that they are used.

5. The perceived cost of hydrogen is the biggest obstacle

The most significant objection raised by our respondents was the cost of energy. 43.7% of respondents agreed with the statement *I fear hydrogen would be too expensive* and 77.2% of respondents said they would be unable or unwilling to pay more for hydrogen than they currently spend on their energy bills. It is therefore possible that any future costs associated with hydrogen blending will be resisted if they are passed down to the public.

6. Safety concerns do not seem insurmountable, but negative perceptions of hydrogen as dangerous are important

At least 44% of participants said they would be quite worried or very worried about the possibility of gas leaks, explosions, and fires. Furthermore, while 77% of respondents were confident that adequate safety precautions would be developed to manage any risks of using hydrogen, the level of initial safety concerns that respondents had was significantly associated with their overall support for hydrogen. This means that negative safety perceptions of hydrogen do exist and are important.

Recommendations for Policy and Practice

1. It is likely that hydrogen blending can proceed without major resistance from the public

Our findings suggest that hydrogen blending will not encounter major resistance, and may even be supported, as a way to begin the decarbonisation of heat in homes without modifying appliances. While there are general safety concerns surrounding hydrogen, particularly regarding the possibility of explosions, the majority of our sample did not have strong positive or negative perceptions about it. After being informed that no appliance modifications would be necessary, our participants seemed to recognise that the environmental impacts of using blended hydrogen would be positive but that any impact on home appliance use would be minimal. Furthermore, when asked to score their overall support for hydrogen, on average our participants were not averse to using hydrogen as a fuel or taking part in blended hydrogen trials. Challenges remain, but in the context of Net Zero our findings indicate that hydrogen blending can be socially acceptable as an interim stepping-stone to the deep, wholesale decarbonisation of heat.

2. Coordinated and focused deliberations need to take place about how best to discuss evidence about hydrogen with the public

As the public's knowledge and awareness of hydrogen is low, a necessary initial step is to collectively consider how hydrogen's profile and its possible role in the UK's renewable energy mix can be communicated to the public. The role of key actors, evidence, and institutions, and their coordination, will be absolutely pivotal to how this is achieved. Our respondents indicated that they would have little trust in the media, and only the Health and Safety Executive and universities were deemed to be particularly trustworthy sources of information. The role of the gas industry and local/national government in fostering dialogue and debate with the public therefore needs to be carefully deliberated upon. In addition, evidence from the upcoming HyDeploy trials and from the Health and Safety Executive need to be disseminated through trusted channels of national communication, and an immediate task is for industry, government, academic and other stakeholders to build, deploy, and maintain these channels effectively.

3. Public involvement 'upstream' of discussions about how the costs and benefits of hydrogen are distributed is essential

The question of how to make hydrogen cost-effective is longstanding among industry and research communities. As hydrogen moves into the mainstream and begins to be used in UK homes over the coming decade, there is an urgent need to better involve the public in these discussions. Not only will this be essential to ensuring that any transition to hydrogen and a wider zero-carbon economy is just, fair, and equitable, our findings suggest that if costs are passed to consumers there will be considerable resistance to and even a rejection of hydrogen as part of the solution to the decarbonisation of heat. We therefore recommend that governmental guidance and policy frameworks for hydrogen must focus not just on technical barriers and enablers, but on enshrining elements of distributive, procedural, and recognitional justice in policy and practice, particularly as they relate to the spatial, social, and economic distribution of the costs and benefits of hydrogen as a fuel for homes.

4. Follow the hydrogen into the home

Survey research is extremely useful for gauging public perceptions of new energy technologies, but less useful at assessing how new innovations like blended hydrogen will change (or not change) the way people actually use their appliances or experience safety in the home. Academic research into hydrogen perceptions has long relied on surveys. The entry of hydrogen to people's homes necessitates a break from this. We need to better understand how customers will engage with blended hydrogen in their homes, how this may differ across different socio-economic, demographic, and vulnerable groups, how familiarity and acceptance is built across time through use, and where any possible user problems might occur. We also need to know in much more depth how blended hydrogen might fold additional risks into people's day-to-day practices of heating, cooking, and using hot water, and how these risks can be mitigated. To do so we recommend that there should be detailed, fine-grained qualitative research undertaken with householders and community groups in areas that will use blended hydrogen in the coming years, research that should ideally be collaborative between government, industry, academia, and the public themselves. Learning from this research should be folded into strategies and policy frameworks for the wider deployment of blended hydrogen in the UK.

1. Introduction

"It is difficult to know quite how acceptable hydrogen will be for heating homes at this stage – although it is likely to be no more dangerous than natural gas, there is a difference between actual safety and perceptions of safety."[3]

1.1. Background and Context

Hydrogen is back on the agenda in the UK. With the release of its Net Zero report in May 2019, the Committee on Climate Change (CCC) has underlined the role that hydrogen may play in the transition to a zero-carbon economy.[4] Until recently, hydrogen's role in the UK's efforts to reduce carbon emissions have predominantly been centred on transport. Hydrogen cars are on the roads, and London and Manchester are both now following Aberdeen's lead in switching petrol for hydrogen in their buses.[5] In parallel, academic research has continued to focus on public perceptions of hydrogen transportation systems, investigating if, why, and how the public are willing to accept hydrogen as a new fuel of everyday mobility.[6]

However, questions remain about hydrogen's wider contribution to the elimination of UK emissions.[7] A key emerging battleground is the home, and particularly domestic heating, which as of 2016 comprised 98% of residential carbon emissions.[8] The phaseout of natural gas is therefore essential, but the capability of electricity to provide heat to UK homes with the efficiency and flexibility that is required to keep residents sufficiently warm is uncertain. In this scenario, it is increasingly envisaged that the UK gas network could be converted to safely accommodate hydrogen by 2050, thus replacing the natural gas presently used in domestic and industrial heating systems.[9] As long as adequate Carbon Capture and Storage (CCS) technologies are in place to offset the carbon that is likely to be generated as a by-product of initial hydrogen production, hydrogen may provide long-lasting and deep decarbonisation of the UK gas network.

The technical challenges of converting existing gas networks to accommodate hydrogen are formidable and beginning to be documented.[10] Other challenges are economic: how can hydrogen contribute to clean, green growth strategies, and how can existing and in many cases struggling industrial clusters benefit from the creation and growth of a hydrogen economy?[11] What are the economic costs of a transition to hydrogen, and how will any costs be distributed throughout society? Another challenge is social. Across much of Europe (and the wider world), public knowledge of hydrogen and its possibilities are consistently demonstrated to be low.[12] The social challenge is therefore a simple yet fundamental one, and hinges on the extent that hydrogen can be understood, accepted, supported, and most importantly *used* by people in their homes and in their domestic energy consumption.

Any full conversion of the UK gas network to accommodate hydrogen is some time away. In the meantime, small amounts of hydrogen will soon be blended into current natural gas supplies. The premise of this idea is to blend hydrogen into the existing gas network in small enough quantities to not require any adjustments to domestic cookers, boilers, and other gas-fired appliances, but in large enough quantities to generate significant, immediate reductions in carbon emissions.[13] In late 2019, a demonstration project – HyDeploy – led by gas distribution network operators Northern Gas Networks and Cadent Gas will be undertaking the first hydrogen blending demonstration project in the UK. The demonstration will be blending 20% vol hydrogen into Keele University's private gas network. This will be followed by two public trials in the North East and North West of England in 2020 and 2021.[14] The broader aim of the trials is to establish the necessary evidence base to prove that hydrogen can safely be blended into the UK gas network without requiring exemptions to existing gas safety laws to be requested on each separate occasion.[15] This is especially significant because, as suggested by HyDeploy, the expected carbon savings from a UK wide deployment of 20% vol blended hydrogen could be the equivalent of taking 2.5 million cars off the road without requiring any change to household appliances.

Blending hydrogen with natural gas does not make the social challenge go away. The CCC have suggested that "[i]t is difficult to know quite how acceptable hydrogen will be for heating homes at this stage – although it is likely to be no more dangerous than natural gas, there is a difference between actual safety and perceptions of safety."[16] In April 2019, the UK's Minister of State for Energy and Clean Growth at the time, Claire Perry MP, noted similar, saying that "there is a huge amount of enthusiasm for hydrogen heating, but there is a question about public perception and how much you can blend."[17] This caution is well-founded – academic research has shown that the only comparable transition in UK history, the transition from 'town gas' to natural gas in the 1960s and 1970s, was plagued by problems caused by unfamiliar appliances, new forms of combustion, and the disruption of day-to-day practices of heating, cooking, and doing laundry in the home.[18]

Presently, questions regarding the public acceptability of hydrogen are driven by three factors. The first concerns difficult and in some cases painful memories of public resistance to renewable energy projects such as wind farms and nuclear power stations, which among other things have highlighted that public perception and acceptance is critical to the successful deployment and diffusion of renewable energy technologies. The second relates to hydrogen specifically, and the unfortunate fact that hydrogen has been central to two of the twentieth century's most prominent cultural and visual spectacles involving explosions – the Hindenburg disaster and the atom bomb. Thirdly and more broadly, there is considerable uncertainty around how the public will perceive hydrogen for heating in relation to cost, safety, and the environment. While there is now a considerable academic literature around perceptions of hydrogen for transportation, especially in connection with refuelling infrastructure, hydrogen cars, and public transport, there has been very little research investigating public perceptions of hydrogen for use in the home.[19]

1.2. This Report

The aim of this report is to add to the discussion surrounding the development of hydrogen in the UK by investigating public perceptions of blended hydrogen as a fuel for UK homes. The research was funded as part of the HyDeploy project, and the writing of the report was supported by Newcastle University and the Engineering and Physical Sciences Research Council. We obtained a sample (n=742) representative of the UK adult population in terms of age, sex, ethnicity, and personal income from a survey administered in March 2019 (see **Appendix A** for full documentation of the methodology). Our survey design was developed following a review of existing academic and policy literatures on the public acceptance of renewable energies and hydrogen technologies.[20]

The report is structured as followed. **Section 2** focuses on our respondents' knowledge, understanding, and initial acceptance of hydrogen. It also investigates our respondents' environmental values and awareness. **Section 3** details the reactions and responses of our participants after they were informed about two pieces of information relating to hydrogen blending in the UK context: that most UK home appliances have been tested to operate on 20% vol blended hydrogen, and that town gas was previously used in the UK and was composed of up to 50% hydrogen. This section subsequently explores the impacts that our respondents thought using blended hydrogen would have on cost, safety, home appliance use, and the environment. **Section 4** considers who and what would be considered trustworthy sources of information and evidence about hydrogen. **Section 5** details our participants' overall support for hydrogen and comments upon the key factors associated with support.

2. Values, knowledge, and general perceptions of hydrogen

Summary:

- Knowledge and awareness of hydrogen was low among our respondents, and this suggests that knowledge of hydrogen will also be low among the UK public
- Environmental awareness was moderately high, with respondents displaying concern about climate change and recognising the need to reduce greenhouse gas emissions
- Perceptions of hydrogen as explosive and dangerous do exist, and the most notable initial negative perception of hydrogen was that it will be expensive
- Overall, hydrogen is neither accepted nor rejected by the public, likely indicating that the majority do not know enough about it to offer a firm opinion

2.1. Knowledge and awareness of hydrogen is low

Academic studies have shown that knowledge of hydrogen among different national populations is consistently low. For example, some scholars, using free word associations, have shown that the most common associations people make with hydrogen are neutral and related to its physical or chemical properties.[21] Other studies have demonstrated that men and those with degree level educations are more likely to know more about hydrogen.[22] Overall, therefore, public knowledge and understanding of the possibilities of hydrogen remains minimal and partly confined to certain demographic groups.

To assess our participants' initial knowledge of hydrogen, we asked them to 'agree' or 'disagree' with certain true/false statements about hydrogen (an option for 'neither agree nor disagree' was also included, and is interpreted here as an incorrect answer). These statements were: K1) *burning hydrogen emits gasses which contribute to climate change* (false); K2) *hydrogen could be used as an energy source for UK homes and businesses* (true); K3) *hydrogen does not emit carbon monoxide when burned* (true).

In all three questions, fewer than half of participants answered correctly. 28.4% of participants answered K1 correctly, 42.3% answered K2 correctly, and 40.4% answered K3 correctly. In such a format, it is probable that participants who did not know the answer to any question would still guess correctly at least once. Therefore, combining participants' responses together shows that 64.4% of participants answered one or no questions correctly, 18.9% answered two correctly, and 16.7% answered all three correctly. This shows that around two thirds of our respondents can be considered not knowledgeable about hydrogen.

In summary, knowledge of hydrogen was low among our participants, and this suggests that knowledge of hydrogen will also be low among the UK public at large. We will return to this later in our discussions of trust, education, and communications.

2.2. Environmental values and awareness are high

As well as knowledge, environmental values and awareness have been shown to shape public perceptions and acceptance of hydrogen. Peter Achterberg has argued that "[t]hose people with high levels of environmental concern will be more willing to embrace new emerging technologies such as hydrogen technology. Those who are not concerned with the environment will expectedly not do so."[23]

To assess our participants' environmental values, we presented them with four statements on the environment and asked them to respond on a five-point scale ranging from 'strongly disagree' to 'strongly agree'. These statements were: E1) *I am not concerned about environmental problems, like climate change and air pollution;* E2) *reducing greenhouse gasses should be one of the main priorities for the UK government;* E3) *we should all be looking to make changes in our everyday lives to combat climate change;* E4) *gas central heating in the UK is a significant contributor to climate change.*

The main finding is that the environmental values and awareness of our participants was moderately high. Over 75% of our participants agreed with statements E2 and E3 and disagreed with statement E1. Statement E4 was treated with more caution by participants, possibly reflecting an uncertainly around the relative extent to which household practices of heating contribute to climate change as a whole. Combining our participants responses into a score and working with a scale of 0 (least environmental values) to 10 (most environmental values), the average score was 7.6.[24] This demonstrates that the environmental awareness and values of our sample was moderately high. We will return to the association between environmental values and support for hydrogen in Section 5.2.

2.3. Initial perceptions of safety are mixed, but not insurmountable

One of the biggest concerns surrounding the public deployment and use of hydrogen is safety, and especially perceptions of safety. While a huge amount of work has been carried out by the HyDeploy consortium to make the technical safety case for hydrogen blending, perceptions of safety are a separate matter. As noted earlier in the report, hydrogen has a particular cultural history in the UK, and there remains the possibility that negative perceptions of hydrogen as explosive, dangerous, or connected to bombs will impede progress. We wanted to therefore understand our participants' initial perceptions of safety.

We asked participants what their main fears and concerns would be about using hydrogen in UK homes. We gave four options: gas leaks, explosions, fires, and carbon monoxide poisoning. Most prominently, at least 44% of participants said they would be quite worried or very worried about gas leaks, explosions, and fires. Explosions were considered particularly worrisome, with 28.4% of participants responding that they would be very worried about their potential occurrence.

Despite this, we found that our participants were mostly confident that adequate safety precautions would manage these risks. When asked to 'agree' or 'disagree' with the statement *I trust that adequate safety precautions would be developed to manage any risks associated with using hydrogen,* 77% of participants agreed, with only 9.1% disagreeing (the remaining 13.9% of participants neither agreed nor disagreed). ***This shows that although there are negative perceptions about the safety of hydrogen, there is simultaneously a strong sense of trust and confidence that these risks would be adequately mitigated prior to any public use of hydrogen.***

2.4. The biggest initial negative perception of hydrogen is that it will be expensive

A final important issue for hydrogen is its cost implications. More specifically, because hydrogen is likely to be more expensive to produce, distribute, and transmit than natural gas, there are unanswered questions about what the costs of hydrogen for homes will be, who will bear that cost, and more broadly how any costs of hydrogen will be justly (or unjustly) distributed across society. This is important because, as we will repeatedly return to throughout this report, cost was a central consideration for our participants in evaluating the possibilities of hydrogen and hydrogen blending.

We asked participants to 'agree' or 'disagree' with the statement *I fear that hydrogen would be too expensive.* 43.1% of participants neither agreed nor disagreed, but 43.7% of participants agreed. Only 13.3% of participants disagreed (note figures do not add to 100% due to rounding). It is probable that the 43.1% of participants who did not agree or disagree believed that they did not know enough, or had thus far not been given enough information, to make a reasoned judgement either way. Nonetheless, it is significant that such a high number of our participants displayed an immediate scepticism about the costs of hydrogen. Sections 3.4. and 5.4. discuss this further, presenting findings *after* participants had been told more about hydrogen blending.

2.5. Hydrogen is neither accepted nor rejected overall

Lastly, we asked participants to respond on a five-point scale ranging from 'strongly disagree' to 'strongly agree' to six statements measuring initial hydrogen acceptance. There is an important terminological point here. There are two different meanings of acceptance in the academic literature on public perceptions of renewable energy.[26] The first is expressed acceptance and the second is revealed acceptance. "Expressed acceptance is the agreement with statements such as 'I would accept a [renewable energy] project in my community,' and revealed acceptance is the act of (non)engaging in activities to promote or prevent [it]."[27] Because blended hydrogen trials had not occurred in the UK at the time our survey was administered, we use the word acceptance to refer to expressed acceptance, and its opposite expressed rejection, here. In addition, although they are often used interchangeably expressed acceptance is not the same as *support*. While expressed acceptance refers more to the passive acquiescence or tolerance of a particular energy project, support denotes an active, positive attitude towards its development and implementation.

On a scale of -1 to 1, where -1 denotes complete rejection and 1 denotes complete acceptance, the average score of our participants was 0.08.[28] Although this indicates marginal acceptance, it shows that the UK public is initially unlikely to either strongly accept or strongly reject hydrogen. Moreover, the middle option of our scale was 'neither agree nor disagree', and this was the most chosen answer for all of our six statements except one. Previous research has indicated that survey participants who choose such an option are likely indicating that they do not know enough about hydrogen to offer a firm opinion, and our findings support this suggestion.[29]

3. The possibilities and pitfalls of hydrogen blending

Summary:

- Once informed about two key aspects of blended hydrogen in the UK context, willingness to use blended hydrogen increased among our respondents
- The environmental benefits of using blended hydrogen were recognised and supported, and the impacts on home appliance use were perceived as negligible
- The overall impact of using blended hydrogen was perceived to be minimal
- The biggest obstacle to widespread deployment of blended hydrogen remains its perceived cost and associated increases in energy bills

3.1. Once informed, people are more willing to use blended hydrogen at home

Given that knowledge and awareness of hydrogen blending should be at least as low among the UK public as their knowledge and awareness of hydrogen in general, this part of our survey provided participants with two carefully selected pieces of information about hydrogen and hydrogen blending in the UK context in turn:

"Since 1993, all appliances manufactured and sold in the UK have been tested to run on a mixture of 77% natural gas and 23% hydrogen. More recent studies have indicated that the addition of up to 20% hydrogen in the natural gas network is unlikely to present any extra risk or affect the day-to-day use of gas appliances, while reducing greenhouse gas emissions significantly."[30]

"Before natural gas became commonly used in the UK, the main gas used by UK homes and businesses was a manufactured mixture called town gas, which was composed of up to 50% hydrogen."

Following each statement, we asked participants if they would be more or less willing to use blended hydrogen as a fuel for UK homes.

In response to the first statement concerning the testing of home appliances, 87.3% of participants said they would be more willing to use blended hydrogen, with 7.7% saying that it would make no difference. Only 5% said they would be less willing to use it. Similarly, 79% of participants said they would be more willing to use blended hydrogen after reading the town gas statement, 14.6% said it would make no difference, and 6.5% said they would be less willing to (note figures do not add to 100% due to rounding).

This shows that informing participants about these two, key pieces of information has a positive effect on their willingness to use hydrogen. This is important not least because these two facts have been highlighted in HyDeploy's communications ahead of the trial at Keele University.[31] Among those who said this information would make no difference, it is possible that they already knew about the information provided. Alternatively, it is also possible that the main factors affecting their willingness to use hydrogen were related to cost or the environment rather than safety or previous use. Nevertheless, ***these positive findings show that once informed about key pieces of information relating to hydrogen blending in the UK context, the UK public should be more willing to use hydrogen in their homes.***

3.2. The environmental impacts of using blended hydrogen are recognised and supported

Following this, we wanted to ask our participants what they thought the impacts of using blended hydrogen in UK homes would be. ***The first key finding is that participants recognised the environmental impacts of using blended hydrogen would be positive.*** 72.4% of participants said they thought using blended hydrogen would have a positive impact on the quality of the local environment, and 79.9% of participants envisaged a positive impact on climate change. Overall, 70.6% of participants envisaged positive environmental impacts while 25.9% thought there would be no impact.

3.3. Perceived impacts on home appliances are minor

A second key finding is that participants believed the impact of using blended hydrogen on their home appliance use would be minimal or, in many cases, non-existent. 53.2% of participants believed there would be no impact on their use of heating and hot water, while 57.4% believed there would be no impact on their cooker use. Moreover, 41.2% of participants said the impact on their heating and hot water use would be positive, while 35.7% responded the same for their cooker use. Less than 7% of participants envisaged a negative impact on either. Overall, 61.7% believed there would be no impact on their home appliance use, with 33.6% believing it to be positive.

However, while positive overall, our participants' perceptions of the impact of using blended hydrogen on safety was more mixed. 62.1% of participants believed that using blended hydrogen would have no impact on home safety, while 61.9% responded that it would have no impact on wider public safety. Notably, some participants believed the safety implications of using blended hydrogen would be negative; 15.6% envisaged a negative impact on safety in the home and 15.8% envisaged a negative impact on public safety. While low, this shows that there are still safety concerns that will need to be addressed before blended hydrogen can be considered safe by the UK public.

In other words, ***our participants trusted that because their appliances have likely been tested already for their compatibility with 20% vol blended hydrogen, there would be no impact on the ways that they actually use them. But, just as importantly, they were less convinced overall that using blended hydrogen would have no impact at all on safety risks.***

3.4. The biggest obstacle remains perceived costs and increases to energy bills

The largest perceived negative impact of using blended hydrogen in UK homes was on the price of gas. In Section 2.4. it was noted that the cost of hydrogen was the biggest initial concern that our participants had about hydrogen, and this is reinforced here. Opinion here was almost exactly split between negative impacts, positive impacts, and no impacts. 33% of participants envisaged a negative impact on the price of gas, 32.7% no impact, and 34.3% a positive impact. While it seems even, this was by far the largest envisaged negative impact highlighted by our participants. This indicates that cost is likely to remain the biggest concern for the public even after information about blended hydrogen is provided.

Later in the survey, we asked our participants if they valued hydrogen, and if so whether they would be willing or able to pay more for it. The results of this question add more depth to the perceived negative impacts on cost by relating them to the public's ability to pay for increased energy bills. In response to this, 41.2% of participants indicated they valued hydrogen but were not willing or able to pay more for it. A further 24% said they valued it, were willing to pay more, but were not able to. Added together, this totals 65.2% of participants who felt unable to pay more for hydrogen. In addition, 12% were not willing to pay any more for hydrogen even though they considered themselves able to. In contrast, 8.1% responded that they did not value hydrogen at all, while only 14.7% said they valued hydrogen and were willing and able to pay more for it.

Together, these findings illustrate that the key policy and governance issue around hydrogen is likely to be cost. In particular, our findings suggest not only an unwillingness and inability to pay more for hydrogen, but a complete split between those who expect it to cost more, less, or the same than natural gas currently does. Put differently, difficult questions have to be asked and careful conversations have to take place from the outset about the costs of the production, distribution, and transmission of hydrogen. Most importantly, these conversations should involve consumers, and not proceed from the assumption that some additional costs, even if small and framed as being worth it for the environmental benefits, could and should be borne by the public.

3.5. The overall impacts of using blended hydrogen are perceived to be minimal

Despite the perceived cost, it is evident that the overall impacts of using blended hydrogen are perceived to be positive or minimal. In other words, very few of our participants believed that, overall, the impacts of using blended hydrogen would be negative. If an average is taken for all our participants' responses to our questions on impact, an 'overall impact' variable is generated.

Using this variable, 58% of our participants believed there would be no overall impact of using blended hydrogen in UK homes. 39.6% said it would be positive, while only 2.4% envisaged a negative impact overall. ***This shows that, overall, the impacts of using blended hydrogen are perceived to be positive or non-existent.*** Of course, this does not account for the emphasis or weight that participants may have attached to particular impacts, but it nonetheless gives an indication of perceptions of overall impact.

4. Public trust

Summary:

- Because public knowledge and understanding of hydrogen is low, the question of what, and who, the public will trust to provide information about it becomes a pivotal one
- Evidence and approval from the Health and Safety Executive was most valued, and scientific evidence and universities were also considered trustworthy
- Case studies were valued by our respondents, particularly those from the UK such as the forthcoming HyDeploy demonstrations
- Local MPs and the media were considered untrustworthy by our respondents
- Perceptions of central government and the gas industry were mixed, with positive and negative perceptions about their role in providing information about hydrogen

4.1. Public trust will shape hydrogen's future

Given that public knowledge and understanding of the possibilities of hydrogen remains low, a key issue concerns the modes of communication and education that will be needed for people to learn about it. In our survey, we limited the information we provided to participants to the two statements discussed in the previous section. However, it should be clear by this point that issues around cost, safety, the economy, and the environment require more clarification and discussion with people, particularly if resistance to hydrogen is to be minimised or avoided.

In turn, this means that the question of what, and who, the public will trust to provide information about hydrogen is a key one. In addition, the immediate UK political and economic context is one defined by people's disillusionment, frustration, and anger at the way different governing bodies, especially the UK government, are handling the UK's withdrawal from the European Union. In this context, we asked our participants a) what kinds of information they would trust about hydrogen, and b) who they would trust to provide this information. The following sub-sections break down the main findings of these questions.

4.2. Evidence and approval from the HSE are most valued

Our findings show that one type of evidence would be most strongly valued by the public. Namely, approval from the Health and Safety Executive was strongly valued by participants, with 47.7% and 14.4% respectively responding that they would have 'a lot of trust' or 'total trust' in this evidence. In addition, 47% and 15.6% of participants respectively responded that they had 'a lot of trust' or 'total trust' in the Health and Safety Executive as an institution. Overall, the Health and Safety Executive was the most trusted of the institutions that we presented to participants, and was far more trusted than government, industry, and universities.

Scientific evidence was also strongly valued by our participants, with 53.2% and 24.3% respectively responding that they would have 'a lot of trust' or 'total trust' in it. This, however, was not conflated by our participants with research emanating from universities. By comparison, 43.4% of participants said they would have 'a lot of trust' in universities, and only 9.3% said they would have 'total trust' in them. ***In other words, approval from the Health and Safety Executive should form an important component of public communications about hydrogen, including the scientific evidence that supports the approval.***

4.3. Case studies will also be valued, especially those from the UK

In our options for this part of the survey we included both UK case studies and European/international case studies as possible types of evidence. This is because there are European blended hydrogen trials that will take place or that are currently taking place, as well as the HyDeploy trials beginning in 2019.[32] We found that participants had more trust in UK case studies than European/international case studies. 40.7% of participants said they would have 'total trust' or 'a lot of trust' in European/international case studies, compared to 51.8% in UK case studies.

Moreover, whereas only 5.3% of participants said they would have 'no trust' or 'little trust' in UK case studies, 12.8% said the same for European/international case studies. This shows that ***both UK and non-UK case studies are trusted to a degree, and that evidence of the success of European blended hydrogen trials will be valuable. However, it is equally clear that once evidence from UK case studies becomes available, this should be foregrounded in communications with the public about hydrogen.***

4.4. The media is perceived negatively

In contrast, local and national media fared worse among our participants. 64.4% and 61.6% of our participants said they had 'no trust' or 'little trust' in local media and national media respectively. In addition, less than 6% of our respondents reported having 'a lot of trust' or 'total trust' in either and just under a third said they had 'some trust' in them.

In the context of the UK's withdrawal from the European Union, the media has been subject to similar levels of scepticism as the UK government. Following the deployment of the survey, however, some stories have emerged that have painted hydrogen for transportation in a positive light, and the BBC reported prominently on the University of Birmingham's development of a hydrogen train.[33] ***Therefore, while our evidence suggests that media coverage of hydrogen would be little trusted in the UK there is a need for more research into how particular segments of the public make sense of and react to such stories, and the extent to which they might influence changes in positive or negative perceptions of hydrogen.***

4.5. Despite the political climate, there is still some confidence in governing bodies

It would be reasonable to expect that, in the current political climate, local and particularly national government might be deemed as untrustworthy as local and national media. However, while our results do show mistrust in local and national government as a reliable source of information and evidence about hydrogen, more respondents said they would have at least 'some trust' in them than 'little trust' or 'no trust'. More specifically, 40.8% of respondents said they would have 'some trust' in national government, while 44.5% said they would have 'some trust' in their local authority. In comparison, 33.7% of respondents said they would have 'no trust' or 'little trust' in national government – this figure was slightly higher at 37.9% for participants' local authorities. Lastly, 25.5% of respondents said they had 'a lot of trust' or 'total trust' in national government, compared to 17.7% who answered the same for their local authorities. ***These results show that despite some scepticism, the public believe there is still a role to play for local and national government in providing information about hydrogen.***

4.6. Local MPs are considered particularly untrustworthy

Despite the modest trust that our respondents displayed towards local government, the same cannot be said of their perspectives towards local MPs. 62% of respondents said they would have 'no trust' or 'little trust' in their local MP. Just over 30% said they would have 'some trust', while only 7.3% of our respondents told us they would have 'a lot of trust' or 'total trust' in their MP. This possibly reflects the perceived inability of MPs to solidify the nature (or perhaps in some cases reverse) the UK's withdrawal from the European Union. It also shows that relations between MPs and their constituents remain fragile, even when it comes to matters such as hydrogen that, on the surface, are unconnected to Brexit.

4.7. Perceptions of the gas industry are mixed

Finally, our findings show that perceptions of the gas industry and industry trials are mixed, with an overall picture that is neither wholly positive nor negative. 45% of our respondents said they would have 'some trust' in the evidence produced by industry trials, and 39.1% said they would have 'a lot of trust' or 'total trust' in it. Only 15.9% of our respondents said they would have 'no trust' or 'little trust' in industry trials. ***This indicates that the evidence base and findings produced from the HyDeploy trials will be valued by the public.***

However, this picture was complicated slightly by our question on the gas industry itself as a trustworthy actor. 37.7% of respondents said they would have 'no trust' or 'little trust' in the gas industry, while in contrast 23% said they would have 'a lot of trust' or 'total trust' in it. The most common response to this question was therefore 'some trust', with 39.2% choosing this option.

It should be noted that the survey was carried out only weeks after Ofgem lifted the price cap for energy bills in January 2019, and it is possible that the subsequent increase in many tariffs negatively impacted these responses. In addition, we did not distinguish between gas suppliers and gas distribution networks in the survey. These caveats aside, ***our findings show that while evidence from industry trials will be valued by the public, the gas industry itself is viewed with more scepticism and mistrust than universities and the Health and Safety Executive.***

5. Overall support for the development of hydrogen

Summary:

- Once informed, support for hydrogen was moderately high, with respondents scoring their support around 7/10 on a subjective scale out of 10
- Support for a trial in respondents' local areas was scored higher than their overall support for hydrogen, indicating it is unlikely the public would support the introduction of hydrogen to their local area any more or less than they would support it elsewhere
- Respondents' environmental values and initial worries about hydrogen's safety shaped their support for hydrogen, but demographic factors such as age were not significant
- The biggest obstacle remains the possible cost of hydrogen, with 77.2% of our respondents unable and/or unwilling to pay more for hydrogen than they currently pay for energy

5.1. Support is moderately high

In this final part of the survey, we wanted to assess our participants' support for hydrogen in light of our survey and the information they had been provided throughout. We deliberately shifted the vocabulary from acceptance to support in an attempt to assess the extent to which people might actively and positively engage with the development of hydrogen as a fuel for their homes after learning more about it, as our participants had done as the survey progressed.

To do this, we asked participants to score their support for hydrogen out of 10 in three different contexts: their support for hydrogen as a fuel for the UK as a whole; their support for hydrogen as a fuel for their local area; and their support for a hydrogen trial taking place in their local area. We then took an average score from the responses to create three overall 'support' scores.

The main finding from this is that support for hydrogen is moderately high. ***Support for hydrogen as a fuel for the UK was scored at 6.89, support for hydrogen as a fuel for participants' local areas was scored at 6.81, and support for a trial taking place in participants' local areas was scored at 7.08.***

In addition, over 60% of participants scored 7, 8, 9, or 10 in each of the three questions. Less than 8% of participants scored 1, 2, or 3 in each of the three questions.

An intriguing finding is that participants' support for a trial in their local area was higher than their general support for hydrogen as a fuel for the UK or their local areas. This is reflected in the amount of participants who scored their support for taking part in a trial as 10: 16.8% compared to 9.3% and 9.8% for the UK and for their local area respectively. Furthermore, the difference in scores between support for the UK and support for their local area is 0.08 and therefore marginal. This is important not just in the context of the forthcoming HyDeploy trials. It shows that what is sometimes termed 'NIMBY'ism, or the tendency of people to resist or oppose a particular infrastructure project in their local area that they would otherwise support if it took place elsewhere, is not present in our responses. ***It therefore seems unlikely that members of the public would support the introduction of hydrogen to their local area any more or less than they would support it elsewhere or more generally.***

5.2. Environmental values and initial worries concerning safety influence support

Of the other factors analysed in our survey, both prior environmental values and our participants' initial worries about safety were significantly associated with support for hydrogen. Environmental values were positively associated with participants' support for hydrogen as a fuel for the UK (0.225**), hydrogen as a fuel for participants' local areas (0.209**), and for a blended hydrogen trial taking place in participants' local areas (0.210**).[34] Put differently, ***this means that people who display or identify as having strong environmental values, awareness, and responsibilities are more likely to support hydrogen.***

Contrarily, initial concerns about safety were negatively correlated with participants' support for hydrogen as a fuel for the UK (-0.336**), as a fuel for participants' local areas (-0.334**), and for a blended hydrogen trial taking place in participants' local areas (-0.316**).[35] This is significant because it shows those participants who had concerns with the safety implications of hydrogen *before* being told about the testing of UK home appliances are still less likely to support hydrogen *after* being informed of this. In other words, this shows that while a majority of participants were more willing to use hydrogen after being informed UK home appliances have been tested, this was often not enough to fully allay the initial concerns of some participants. This suggests that while this information is important, there are other factors at play that will influence perceptions of safety and, therefore, the public's support for hydrogen as a whole.

5.3. Demographics are not strongly associated with support or resistance

Although previous studies have suggested otherwise, we found no significant statistical relationships between support for hydrogen (nationally, locally, or for a trial) and demographic variables of age, sex, ethnicity, highest level of educational qualification, or income. Of these variables, we did find that men scored their support for hydrogen higher than would be expected if no association was present. At the same time, we similarly found that women scored their support for hydrogen lower than would be expected if no association was present. However, the statistical significance of these relationships was found to be weak.

5.4. Cost is key

Lastly, across our survey the most important concern raised by participants was the possible costs of hydrogen. In Section 2.4. the cost of hydrogen was the biggest initial concern that our participants had about hydrogen before being informed about two of its key features. In Section 3.4., while the overall impacts of blended hydrogen envisaged by our participants were positive or non-existent, the price of gas was still their biggest concern. In addition, 65.2% of participants felt unable to pay more for hydrogen and a further 12% were not willing to pay any more for hydrogen even though they considered themselves able to. Juxtaposed with other results from the survey, it would appear that there is an emerging situation in the UK where low-carbon technologies and initiatives such as hydrogen are valued by the public and align strongly with prior environmental attitudes, but squeezed incomes and rising energy costs make people unable or unwilling to pay more towards them. ***This is a fundamental challenge, and the ways the costs of hydrogen (and other low-carbon technologies) are governed, distributed, and incorporated into the UK energy system is likely to be pivotal to the wider success or failure of Net Zero.***

Appendix A: Methodology

The aim of this research was to design and deploy a survey that would enable the collection of quantitative data on public perceptions of hydrogen and hydrogen blending in the UK. To do this we developed a quota sampling methodology to obtain a sample representative of the UK adult population. We did this in two steps. Firstly, we deployed our survey through an online survey response collection panel to obtain a large dataset (n>1000) of responses. Secondly, we employed a quota sampling technique to select for analysis from this large dataset a slightly smaller (n>500) sample that was representative of the adult population of the UK in terms of age, sex, ethnicity, and personal income.

The purpose of this Appendix is to document these processes and the decision-making that shaped them. We structure the Appendix based on the two steps described above. We first discuss the deployment of the survey, followed by the quota sampling process that resulted in the final dataset. The final dataset (n=742) used in the research report is available upon reasonable request for purposes of replication or for statistical testing. Further statistical testing would doubtless build a deeper and more nuanced picture than the one that we have presented in this report, and we would welcome the opportunity to explore this further with potential collaborators.

A-1: Online survey deployment and data collection

Our sampling methodology was centred on the need to create a large initial dataset of responses from which smaller, representative datasets could be extracted through quota sampling. We therefore used an online survey response collector or 'panel' to obtain our initial dataset. The use of panels is widespread in academic survey research, and their premise is to offer an incentive for participants to complete an online survey. There are a number of different platforms that offer this service, and in this research we made use of Prolific.[36] Like other panels, Prolific connects academic researchers conducting survey research to its panel of potential participants, and research has found that respondents to surveys administered through Prolific produce high quality data that is at least as reliable as available alternatives.[37] Crucially, Prolific also allows researchers to screen out certain groups of participants whose identities or personal attributes make them unsuitable for their study. Making use of this function allowed us to gather responses only from UK residents and eliminate the possibility of non-UK residents responding to the survey. There is a certain ambiguity to this, in that Prolific does not verify the locations of its panellists and instead relies on their honesty in self-describing their current country of residence. On balance, however, we did not feel that this represented a problem and made the decision to trust this self-reported attribute.

Most importantly, Prolific's screening function allows that a survey can be seen and taken only by panellists that meet specific demographic criteria. Initially, we wanted to obtain a large dataset evenly spread across different bands of age, sex, and personal income. This is because we would then be able to more efficiently use a quota sampling technique to extract a smaller, UK representative sample. We therefore deployed the survey to 18 different demographic groups, whereby Prolific's UK resident panellists could only see the specific survey that corresponded to the group they fell into. Table One below shows these groups. We did not explicitly screen for ethnicity, reasoning that a sufficient and proportionate number of respondents for quota sampling would be gathered by screening only for age, sex, and personal income.

	Higher Income (>£30k)		Middle Income (£20k - £30k)		Lower Income (<£20k)	
	Male	Female	Male	Female	Male	Female
Young Adults (18-38)	1 (HiMYo)	2 (HiFYo)	3 (MiMYo)	4 (MiFYo)	5 (LiMYo)	6 (LiFYo)
	43 *(69)*	48 *(71)*	35 *(70)*	38 *(42)*	48 *(67)*	48 *(79)*
Middle Age (39-59)	7 (HiMMa)	8 (HiFMa)	9 (MiMMa)	10 (MiFMa)	11 (LiMMa)	12 (LiFMa)
	44 *(70)*	45 *(68)*	36 *(70)*	35 *(71)*	50 *(66)*	50 *(72)*
Older Adults (60+)	13 (HiMOa)	14 (HiFOa)	15 (MiMOa)	16 (MiFOa)	17 (LiMOa)	18 (LiFOa)
	38 *(59)*	42 *(62)*	31 *(31)*	25 *(25)*	37 *(54)*	49 *(69)*

Table One: Sample Structure. The bottom of each cell shows the number of total respondents to the survey in each demographic group in brackets, alongside the number of respondents that were selected out of this total for inclusion in the sample.

We screened for these specific demographic characteristics for the following reasons. Firstly, age, sex, and ethnicity are commonly accepted demographic characteristics by which to create nationally representative samples. Secondly, we also included personal income in our methodology to embed a socio-economic component into the sample. This ensured that our sample had a spread of respondents from different income categories, thus reducing the possibility of skew towards certain socio-economic groups.

We initially obtained 1180 responses to our survey through Prolific. Once duplicate and incomplete responses were removed, the large initial dataset from which we subsequently quota sampled contained 1115 responses. The distribution of these responses across each group can be seen in Table One.

A-2: Quota sampling

To select the correct number of respondents from each group to create our UK representative sample, we first calculated the distribution of the adult UK population as it corresponded to our groups. To do this we used publicly available datasets released by the UK government. We then calculated the number of respondents that would need to be taken from each of our 18 groups to correspond to the UK population (see Table One). Our calculations as well as the composition of our final sample (n=742) are detailed below:

Age: To select a representative proportion of ages in our sample, we calculated the distribution of UK adults that fell into our three groups or age bands: 18-38, 39-59, and 60 and over. To do this we used the mid-2017 estimates of the UK population released by the Office for National Statistics.[38]

	UK Adult Population	Sample
(18-38)	18,213,193	260
	35.0%	35.0%
(39-59)	18,277,346	260
	35.1%	35.0%
(60+)	15,587,986	222
	29.9%	29.9%

Table Two: Sample Structure by Age Bands. Note percentages to not add up to 100% due to rounding.

Sex: To select a representative proportion of sex in our sample, we again used the mid-2017 estimates of the UK population released by the Office for National Statistics.[39]

	UK Adult Population	Sample
Male	25,426,579	361
	48.8%	48.7%
Female	26,651,946	381
	51.2%	51.3%

Table Three: Sample Structure by Sex.

Ethnicity: As we did not explicitly screen for ethnicity, our data is less exact in its correspondence to the actual distribution of ethnicity in the UK. We take these figures from the UK 2011 Census and do not exclude non-adults from the UK population figures.[40]

	UK Adult Population	Sample
White Caucasian	55,073,552	646
	87.2%	87.1%
Mixed/Multiple	1,250,229	26
	2%	3.5%
Asian/Asian British	4,373,339	24
	7%	3.2%
Black/African/Caribbean/ Black British	1,904,684	19
	3%	2.6%
Other Ethnicities	580,374	27
	0.9%	3.6%

Table Four: Sample Structure by Ethnicity. Note percentages do not add to 100% due to rounding.

Personal Income: To select a representative proportion of incomes in our sample, we calculated the distribution of UK adults that fell into our three personal income groups: lower (£20,000>), middle (£20,000-£29,999) or higher (£30,000<). To do this we used the UK government's calculation of the percentile points of personal income from the Survey of Personal Incomes.[41] The latest available data for these calculations is 2016-2017.

	UK Adult Population	Sample
Lower Income	38%	38%
Middle Income	27%	27%
Higher Income	35%	35%

Table Five: Sample Structure by Personal Income.

This process resulted in a final sample of 742 responses from participants representative of the UK adult population in terms of age, sex, ethnicity, and personal income. In cases where our demographic groups had more suitable respondents than could have been selected for our sample, we assigned each participant a random number in Microsoft Excel and chose those responses that had the lowest numbers. Once the quota sampling process had taken place, the final dataset was manipulated in Microsoft Excel then imported into IBM SPSS Statistics to await analysis.

Appendix B: Notes

[1] Oral evidence given by Claire Perry MP to the Science and Technology Committee's enquiry into Technologies for Meeting Clean Growth Emissions, 23rd April 2019. Available at: <http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/science-and-technology-committee/technologies-for-meeting-clean-growth-emissions-reduction-targets/oral/101230.html> [Last accessed 22/10/2019]

[2] HyDeploy is being delivered by the HyDeploy consortium – led by Cadent and Northern Gas Networks, alongside Progressive Energy Ltd, Keele University, HSE – Science Division and ITM Power. See www.hydeploy.co.uk.

[3] Committee on Climate Change (2018) *Hydrogen in a low-carbon economy*, p.27. Available at: <https://www.theccc.org.uk/publication/hydrogen-in-a-low-carbon-economy> [Last accessed 22/10/2019]

[4] Committee on Climate Change (2019) *Net Zero – The UK's contribution to stopping global warming.* Available at: <https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming> [Last accessed 22/10/2019]

[5] See The Guardian (2019) *London to have world-first hydrogen-powered doubledecker buses; Gas World (2019) Liverpool City Region to trial hydrogen buses;* Aberdeen City Council (2019) *Aberdeen's pioneering hydrogen bus project arrives at major milestone.*

[6] In the UK context, see especially Bellaby, P; Upham, P; Flynn, R; and Ricci, M. (2016) Unfamiliar fuel: How the UK public views the infrastructure required to supply hydrogen for road transport, *International Journal of Hydrogen Energy* 41 (15): 6534-6543.

[7] See especially: Staffell, I; Scamman, D; Abad, A.V; Balcombe, P; Dodds, P.E; Ekins, P; Shah, N. and Ward, K.R. (2019) The role of hydrogen and fuel cells in the global energy system, *Energy and Environmental Science* 12: 463-291; Dodds, P.E; Staffell, I; Hawkes, A.D; Li, F; Grünewald, P; McDowall, W. and Ekins, P. (2015) Hydrogen and fuel cell technologies for heating: A review, *International Journal of Hydrogen Energy* 40: 2065-2083.

[8] Parliamentary Office of Science and Technology (2016) *Carbon Footprint of Heat Generation.* Available at: <http://researchbriefings.files.parliament.uk/documents/POST-PN-0523/POST-PN-0523.pdf> [Last accessed 22/10/2019]

[9] See especially the work of Paul Dodds: Dodds, P.E. (2013) The future of the UK gas network, *Energy Policy* 60: 305-216; Dodds, P.E. and Demoullin, S. (2013) Conversion of the UK gas system to transport hydrogen, *International Journal of Hydrogen Energy* 38 (18): 7189-7200.

[10] For reviews see the above articles by Paul Dodds, and: Staffell et al, The role of hydrogen and fuel cells (note 7); Committee on Climate Change, *Hydrogen in a low-carbon economy* (note 3).

[11] For example, the HyNet project aims to reduce carbon emissions from a combination of CCS and hydrogen while supporting the economic development and growth of the North West of England. Similarly, Teesside is attempting to position itself as the first Net Zero cluster in the UK through the Tees Valley Hydrogen Innovation Project. Both projects aim to use pre-existing industrial capacity to stimulate local and regional clean growth. See www.hynet.co.uk and www.tees.ac.uk/sections/business/consultancy/bhe.cfm.

[12] E.g. Achterberg, P. (2014) The changing face of public support for hydrogen technology explaining declining support among the Dutch (2008-2013), *International Journal of Hydrogen Energy* 39: 18711-18717; Thesen, G. and Langhelle, O. (2008) Awareness, acceptability and attitudes towards hydrogen vehicles and filling stations: a Greater Stavanger case study and comparisons with London, *International Journal of Hydrogen Energy* 33: 5859-5867.

[13] Isaac, T. (2019) HyDeploy: The UK's First Hydrogen Blending Deployment Project, *Clean Energy* 3 (2): 114-125.

[14] See www.hydeploy.co.uk.

[15] Isaac, HyDeploy (note 13).

[16] Committee on Climate Change, *Hydrogen in a low-carbon economy* (note 3), p.27.

[17] Oral evidence given by Claire Perry MP (note 1).

[18] Arapostathis, S; Laczay, S. and Pearson, P.J.G (2019) Steering the 'C-Day': Insights from the rapid, planned transition of the UK's natural gas conversion programme, *Environmental Innovations and Societal Transitions* 32: 122-139.

[19] An exception to this trend is some work in the Australian context that has looked at the viability of using hydrogen as a fuel for homes. See Lambert, V. and Ashworth, P. (2018) The Australian public's perception of hydrogen for energy. Queensland: University of Queensland. Available at: <https://arena.gov.au/assets/2018/12/the-australian-publics-perception-of-hydrogen-for-energy.pdf> [Last accessed 22/10/2019]

[20] Specifically, see: de Best-Waldhober, M; Daamen, D. and Faaij, A. (2009) Informed and uninformed public opinions on CO2 capture and storage technologies in the Netherlands, *International Journal of Greenhouse Gas Control* 3 (3): 322-332; Schmidt, A. and Donsbach, W. (2016) Acceptance factors of hydrogen and their use by relevant stakeholders and the media, *International Journal of Hydrogen Energy* 41 (8): 4509-4520; Thesen and Langhelle, Awareness, Acceptability, and Attitudes (note 12).

[21] Ricci, M; Bellaby, P. and Flynn, R. (2008) What do we know about public perceptions and acceptance of hydrogen? A critical review and new case study evidence, *International Journal of Hydrogen Energy* 33 (21): 5868-5880; Sherry-Brennan, F; Devine-Wright, H. and Devine-Wright, P. (2010) Public understanding of hydrogen energy: A theoretical approach, *Energy Policy* 38 (10): 5311-5319.

[22] Achterberg P, Houtman D, Bohemen S v and Manevska K (2010) Unknowing but supportive? Predispositions, knowledge, and support for hydrogen technology in the Netherlandsv, *International Journal of Hydrogen Energy* 35(12): 6075–6083; AcIribarren, D; Martín-Gamboa, M; Manzano, J. and Dufour, J. (2016) Assessing the social acceptance of hydrogen for transportation in Spain: An unintentional focus on target population for a potential hydrogen economy, *International Journal of Hydrogen Energy* 41 (10): 5203-5208.

[23] Achterberg, P. (2012) Knowing hydrogen and loving it too? Information provision, cultural predispositions, and support for hydrogen technology among the Dutch, *Public Understanding of Science* 23 (4): 445-452, p.447.

[24] 95% confidence interval of 7.45-7.7, Cronbach's Alpha 0.695.

[25] Committee on Climate Change, *Net Zero* (note 4), pp.246-248; Committee on Climate Change, *Hydrogen in a low-carbon economy* (note 3), pp.110-111.

[26] Following Seigo, S.L; Dohle, S. and Siegrist, M. (2014) Public perception of carbon capture and storage (CCS): A review, *Renewable and Sustainable Energy Reviews* 38: 848-863.

[27] *Ibid,* p.850.

[28] 95% confidence interval of 0.06-0.1, Cronbach's Alpha 0.778.

[29] *Ricci et al,* What do we know about public perceptions and acceptance of hydrogen? (note 21), p.5872.

[30] All home appliances manufactured and sold in the UK after 1993 have been subject to a short-term test to run on up to 23% hydrogen. This testing is carried out under the (2009/142/EC) Gas Appliance Directive (GAD).

[31] See pages on the HyDeploy website on town gas and home appliances.

[32] A list of completed, ongoing, or planned projects can be found in Quarton, C.J. and Samsatli, S. (2018) Power-to-gas for injection into the gas grid: What can we learn from real-life projects, economic assessments and systems modelling?, *Renewable and Sustainable Energy Reviews* 98: 302-316, p.306.

[33] BBC (2019) Hydrogen trains: Are these the eco-friendly trains of the future?

[34] ** = significant at the p<0.01 level.

[35] We created an 'overall worry' variable by taking an average of participants' responses to our questions about how worried they would be about the risks of fires, gas leaks, explosions, and carbon monoxide poisoning if they used hydrogen. This does not take into account the weight participants may have applied to each risk, but nonetheless the variable is useful an indication of how worried participants were about using hydrogen in general. Because each of the four risks are independent of each other, and not intended to be measured as scale items, any Cronbach's Alpha value is unsuitable and thus not reported here.

[36] See https://www.prolific.co

[37] Peer, E; Brandemarte, L; Samat, S. and Acquisti, A. (2017) Beyond the Turk: Alternative platforms for crowdsourcing behavioral research, *Journal of Experimental Social Psychology* 70: 153-163.

[38] Office for National Statistics (2019) *Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland.* Available at: <https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland> [Last accessed 22/10/2019]

[39] *Ibid.*

[40] Accessible through: https://www.nomisweb.co.uk.

[41] Accessible through: https://www.gov.uk/government/statistics/percentile-points-from-1-to-99-for-total-income-before-and-after-tax [Last accessed 22/10/2019].

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